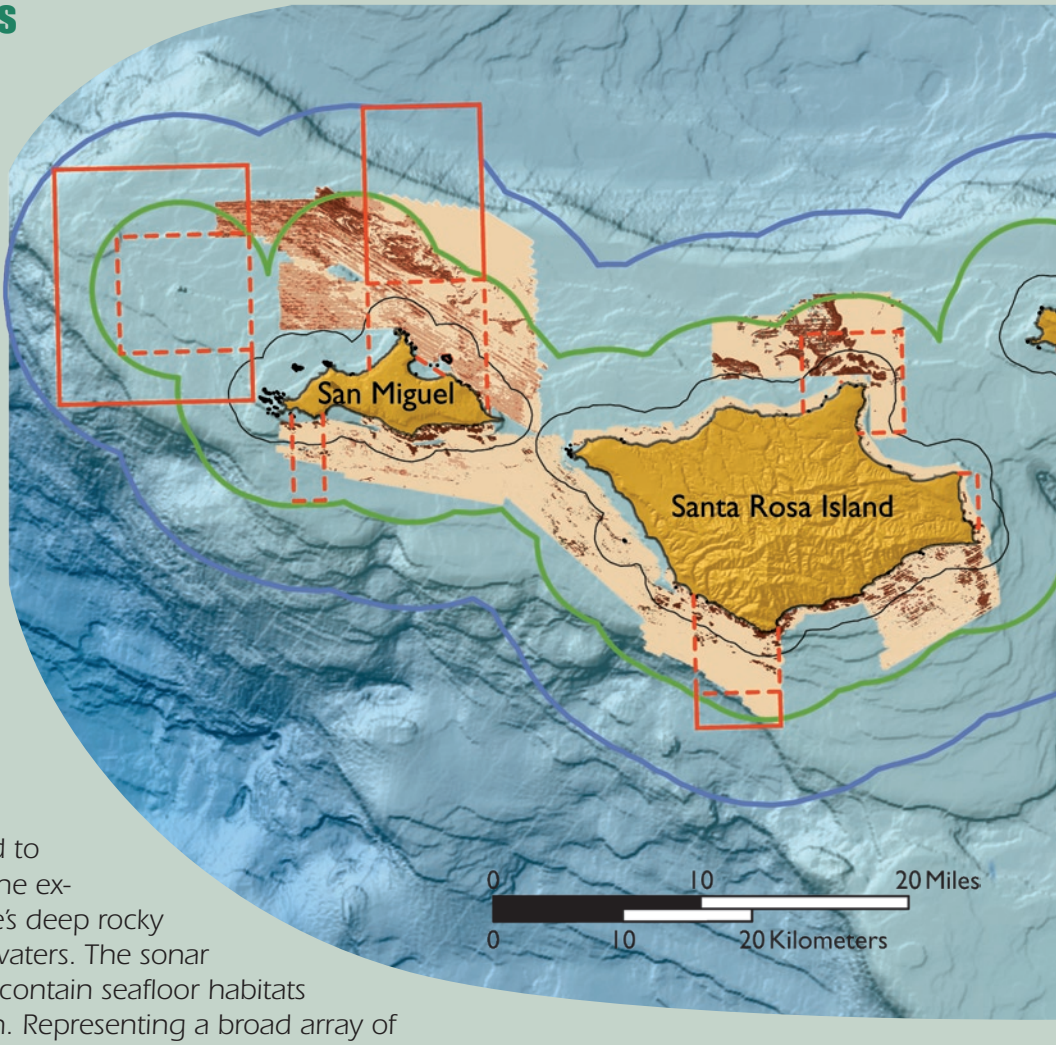
biological and habitat monitoring

Mapping Seafloor Habitats

One goal for design of MPAs at the Channel Islands was to include portions of each seafloor habitat type to protect distinct biological communities associated with the habitats. Scientists from the U.S. Geological Survey and California State University, Monterey Bay, have used swath sonar to map seafloor habitats at varying depths around the Channel Islands. As of 2008, the scientists had mapped approximately 30% of the Channel Islands National Marine Sanctuary (see map). All MPAs surveyed to date contain both rocky reefs and soft bottom areas. Mapped rocky reefs tend to be located in shallow waters with the exception of Footprint Marine Reserve's deep rocky ridge, which lies mainly in federal waters. The sonar mapping data show that the MPAs contain seafloor habitats that are representative of the region. Representing a broad array of habitats and their associated species was a goal for the Channel Islands MPAs and is required for comparing MPAs with surrounding areas.

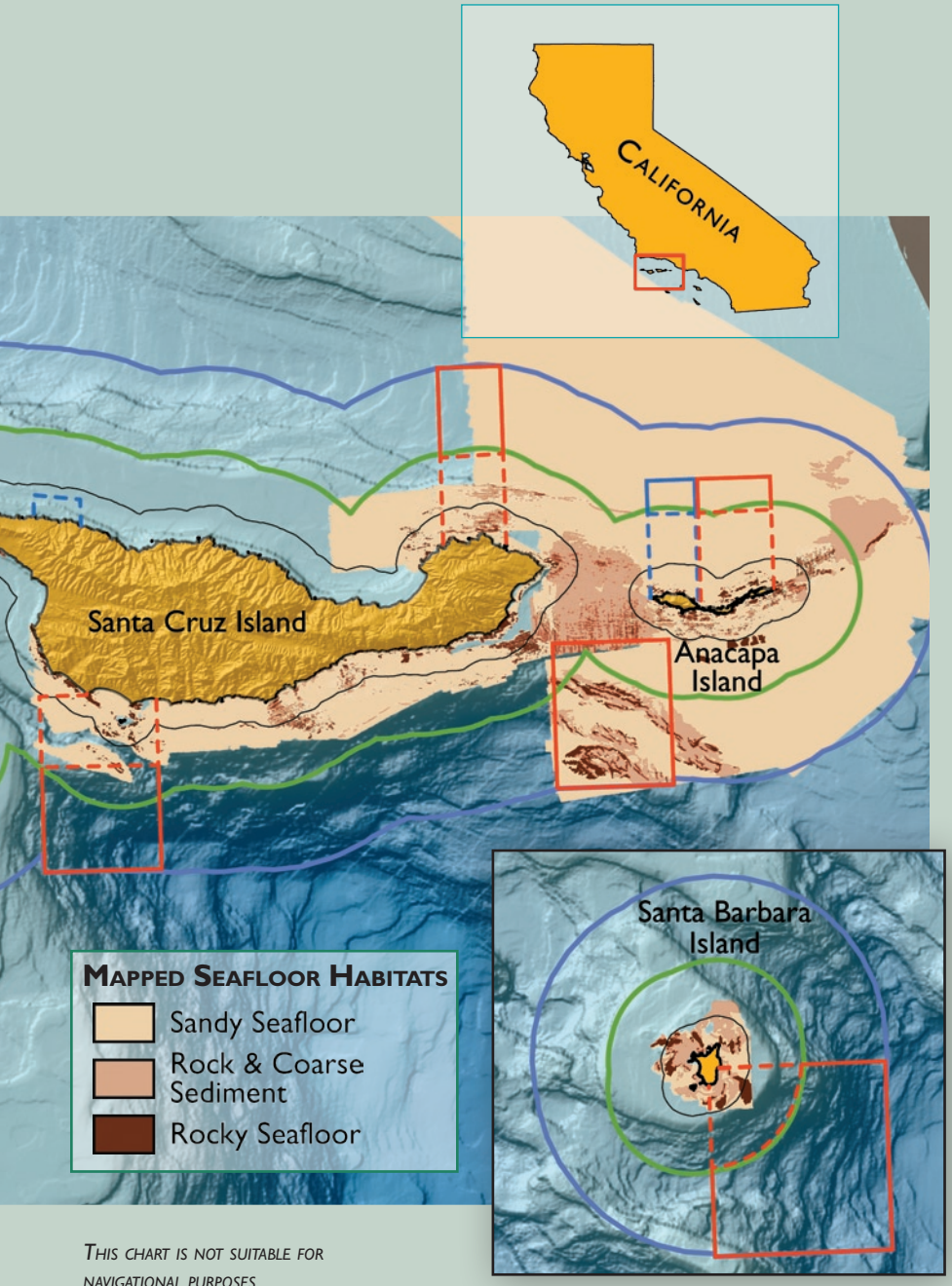


Data: United States Geological Survey and California State University, Monterey Bay. Analysis: G. Cochrane and R. Kvitek.

Long-term Monitoring of Marine Ecosystems

In the ocean, habitats are connected through movements of animals, plants, and nutrients. Most marine fishes and invertebrates use more than one habitat during their lives. Areas with diverse habitats also tend to be biologically diverse. The Channel Islands region supports a wide array of habitats and species including habitat-forming species, such as giant kelp, species targeted by fishing, such as lobster and rockfish, and non-targeted species, such as sea anemones and garibaldi fish. The surrounding waters support at least 27 species of whales and dolphins, and the islands are home to feeding and breeding colonies of seals, sea lions, and more than 60 species of marine birds.

Monitoring the ecosystem that supports these species is critical to understanding changes over time. Long-term monitoring data are not common in marine systems, but the Channel Islands are an exception. Since 1982, the Channel Islands National Park (CINP) has been conducting comprehensive surveys of the kelp forest habitat and associated species. CINP also conducts monitoring of intertidal areas, beaches, and onshore animals. These surveys and other ongoing monitoring and research programs provide substantial baseline information, and they allow for better comparisons before and after implementation of MPAs.



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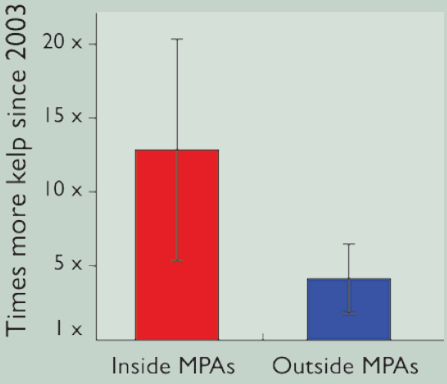
Reef at Harris Point. *Photo: © Jim Knowlton*

Key Findings

- Kelp forests, rocky reefs, and sandy areas are common seafloor habitats around the Channel Islands.
- The Channel Islands MPAs contain amounts of rocky and soft-bottom seafloor habitats that are representative of the region.
- The MPAs protect a diverse community of fishes, invertebrates, mammals, and birds representative of the Channel Islands.
- Kelp forests have expanded around the Channel Islands since 2003.

Relative Change in Kelp



Change in kelp from before (1998-2002) to after (2003-2007) establishment of MPAs. Proportional increase in kelp was greater in MPAs (red bar) than other areas (blue bar).

Changes in Kelp Forests

Giant kelp forms extensive underwater forests firmly attached to rocky reefs in shallow waters around the Channel Islands. Giant kelp forests provide food and habitat for many associated fishes and invertebrates. The fronds of giant kelp, which can grow as fast as 2 feet per day, float at the ocean surface making it possible to map surface area of kelp from aerial photographs. For many years, scientists from the California Department of Fish and Game mapped kelp forests at the Channel Islands. A scientist from the University of California, Santa Barbara, used historical aerial surveys, infrared aerial photography, and recent advances in satellite remote sensing to evaluate changes in kelp forests in the region. He found that kelp abundance increased substantially throughout the Channel Islands region during the 5 years since MPAs were established as compared to the previous 5 years. Additionally, these increases were greater in MPAs than other areas.

Data and analysis: B. Kinlan.

Do More Fish and Invertebrates Live Inside Marine Reserves?

Scientific Scuba Surveys

According to scuba surveys, fish species actively targeted by fishermen outside reserves tend to be bigger and more plentiful inside reserves than in fished areas at the Channel Islands. The Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) and the Channel Islands National Park (CINP) conducted dive surveys at more than 80 shallow, rocky sites inside and outside of marine reserves. They studied 14 fish species that are targeted by commercial and recreational fishermen, such as rockfish, kelp bass, and lingcod, and 19 fish species that are not targeted, such as bat ray, garibaldi, and señorita. At each site, divers counted and estimated sizes of fish, allowing calculation of biomass, or total weight of fish in a defined area. Twelve of the 14 species fished outside reserves had greater biomass inside marine reserves. In contrast, biomass of almost all non-targeted species was similar or greater outside reserves. Most dramatically, ocean whitefish and lingcod—both of which are fished outside reserves—had more than 3 times greater biomass inside reserves. Similarly, invertebrates targeted by fishing tended to be more abundant in reserves. Researchers are examining possible reasons for these patterns, such as differences in habitat. However, strong differences between targeted and non-targeted species suggest that protection from fishing is a likely cause.

Data: PISCO & CINP. Analysis: J. Caselle, S. Hamilton, D. Malone, D. Kushner, and M. Carr.

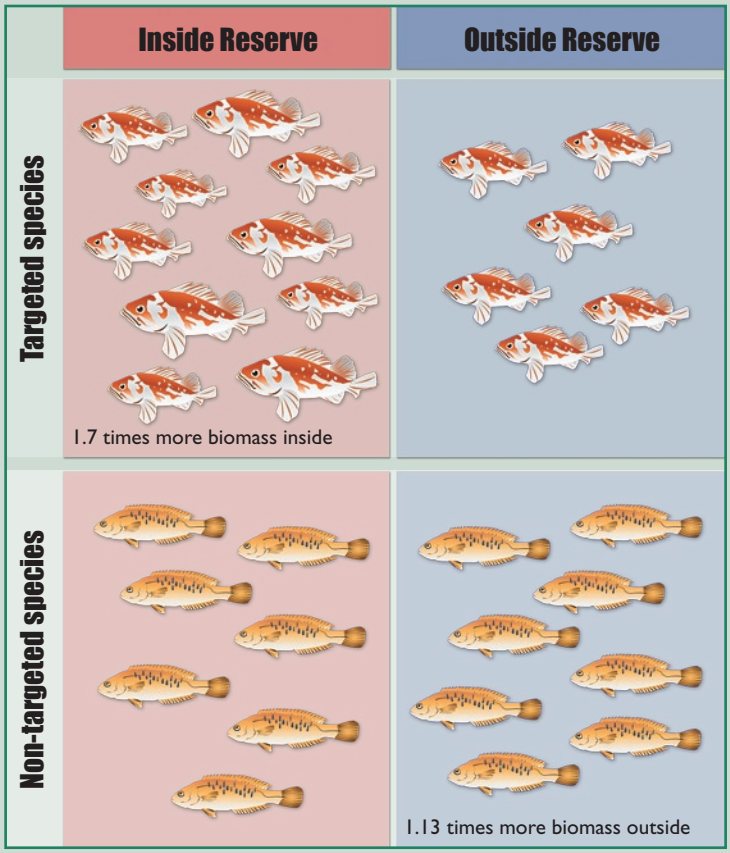
Fish Species from PISCO Surveys

Non-targeted species	Targeted species
Rock wrasse (1.66)	**Ocean whitefish** (4.53)
Island kelpfish (1.15)	***Lingcod** (3.21)
Rubberlip surfperch (1.09)	***California sheephead** (1.88)
Painted greenling (1.06)	**Kelp bass** (1.70)
Pile surfperch (1.04)	***Copper rockfish** (1.66)
Blacksmith (0.97)	**Cabezon** (1.59)
Bat ray (0.97)	***Olive rockfish** (1.52)
Black surfperch (0.96)	***Blue rockfish** (1.50)
Opaleye (0.96)	***Vermilion rockfish** (1.31)
Striped surfperch (0.94)	**Kelp rockfish** (1.19)
Kelp surfperch (0.91)	**Brown rockfish** (1.14)
Shiner surfperch (0.83)	**Black and yellow rockfish** (1.08)
Garibaldi (0.78)	*Gopher rockfish (0.90)
Halfmoon (0.77)	*Treefish (0.64)
Giant kelpfish (0.76)	
*Señorita (0.74)	
Rainbow surfperch (0.50)	
Silverside (0.44)	
Tubesnout (0.34)	

**Surveys conducted with a remotely operated vehicle (ROV) detected similar results in deeper waters for species (indicated with *) that live in both shallow and deep waters. See opposite page.*

Green: species with more biomass inside reserves.
Black: species with less biomass in reserves. Number in parentheses is ratio of biomass inside to outside reserves. Ratio above 1 indicates more biomass inside reserves.

Effects of Reserves on Average Fish Biomass



The figure above illustrates the differences in fish biomass inside and outside marine reserves at the Channel Islands. Top 2 panels: On average, the biomass of fish species targeted by fishing was approximately 1.7 times greater inside reserves than outside. Bottom 2 panels: In contrast, the average biomass of non-targeted fish species was almost the same inside and outside reserves. Similar patterns were observed for targeted and non-targeted invertebrates.

Differences in fish biomass and invertebrate density inside versus outside reserves.

	Fish	Invertebrates
Targeted	1.7 ± 0.27	1.43 ± 0.50
Non-targeted	0.87 ± 0.07	0.95 ± 0.22

Values greater than 1 indicate more biomass inside reserves. Values less than 1 indicate more biomass outside reserves.

Key Findings

- Fish and invertebrate species targeted by fishermen outside reserves had greater average biomass and density inside marine reserves.
- The average biomass and density of species not targeted by fishermen were similar or slightly greater outside reserves than inside reserves.

Research vessel at Santa Cruz Island. *Photo: Robert Schwemmer/NOAA*

Remotely operated vehicle (ROV) used for deep-water surveys. *Photo: Donald Baldwin/DFG*

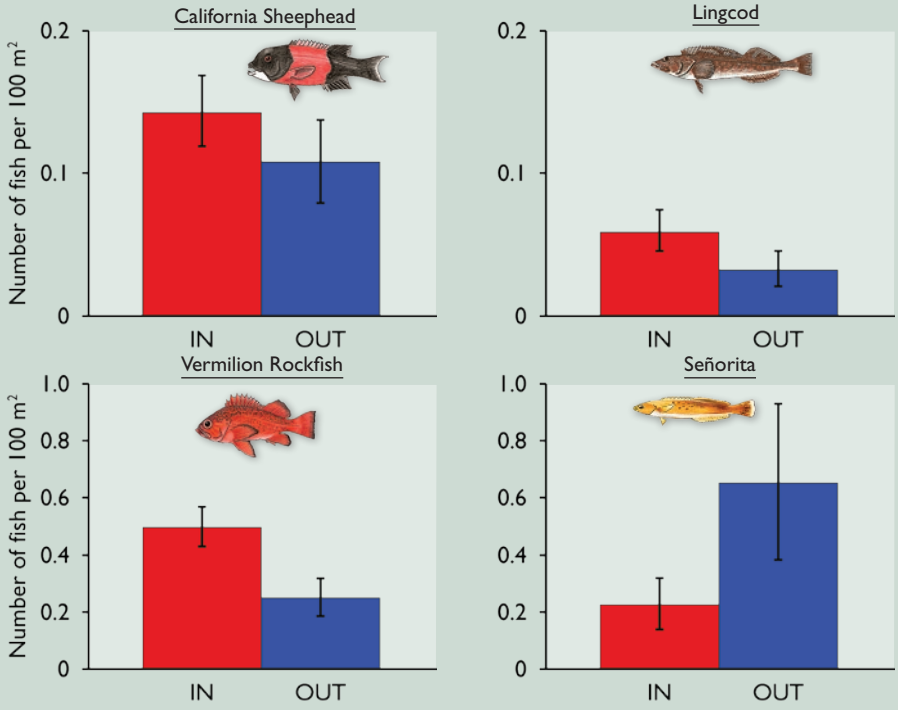
A diver conducts a fish survey for the Reef Environmental Education Foundation (REEF). *Photo: Pete Naylor*

Remotely Operated Vehicle (ROV) Surveys

Since 2004, California Department of Fish and Game scientists have used a remotely operated vehicle (ROV) to survey fish in deeper, rocky habitats around the Channel Islands. These surveys have covered a total of 150 miles (240 kilometers) at 10 different sites at depths of 45 to 220 feet (14 – 67 meters), extending beyond the maximum practical scuba survey depth of about 80 feet (24 meters, see opposite page for scuba surveys). Although it is too soon to see long-term changes, the ROV surveys have found that 8 out of 12 fish species are more numerous in marine reserves. Seven of those 8 species are targeted by fishermen outside the reserves. This finding is consistent with data from scuba surveys in shallower waters.

Data: California Department of Fish and Game, National Oceanic and Atmospheric Administration, Pacific States Marine Fisheries Commission, Marine Applied Research and Exploration, The Nature Conservancy, and Ocean Protection Council. Analysis: K. A. Karpov, A. Lauermann, and J. J. Geibel.

Fish Density Inside and Outside Reserves



Volunteer Reef Survey

Since 1996, volunteer scuba divers have carried out more than 1,700 fish counts at the Channel Islands under the Reef Environmental Education Foundation (REEF) survey program. Prior to establishment of marine reserves in 2003, the REEF divers performed 767 surveys at more than 100 sites around the islands. Subsequently, they have conducted 984 surveys inside and outside the reserves. Scientists are using the data to help understand how marine reserves affect fish abundance. Preliminary results suggest that most fish species in the surveys have increased since the reserves were established.

Data: REEF. Analysis: B. X. Semmens, S. L. Katz, and K.V. Pattengill-Semmens.

ROV Survey Results

Density in reserves (IN)

Density in fished areas (OUT)

Vermilion rockfish, sheephead, and lingcod were more abundant inside no-take reserves (red bars) than outside (blue bars). These 3 species are targeted by fishermen outside reserves. Fishermen do not target the señorita, which was more abundant outside reserves. Data are averages from 2005 through 2007. Many factors might have caused the differences, such as historical abundance, habitat characteristics, interactions among species, or the protection provided in reserves. Scientists may be able to identify the cause of these differences with additional monitoring.

Numbers, Body Sizes, and Movement of Lobster

Lobster trap buoy at Gull Island State Marine Reserve. *Photo: Matt Kay*

Collaborative reserve sampling aboard commercial vessel. *Photo: Kristine Faloon*

California spiny lobster. *Photo: Matt Kay*

Collaborative Reserve Monitoring

CALobster is a research collaboration of commercial fishermen and marine biologists from the University of California, Santa Barbara. The researchers use traps to monitor California spiny lobster around the eastern Channel Islands. They deploy commercial lobster traps inside, nearby, and approximately 2 miles away from 4 reserves. Every trapped lobster is measured and then released with a numbered tag, which stays attached even after the lobster molts.

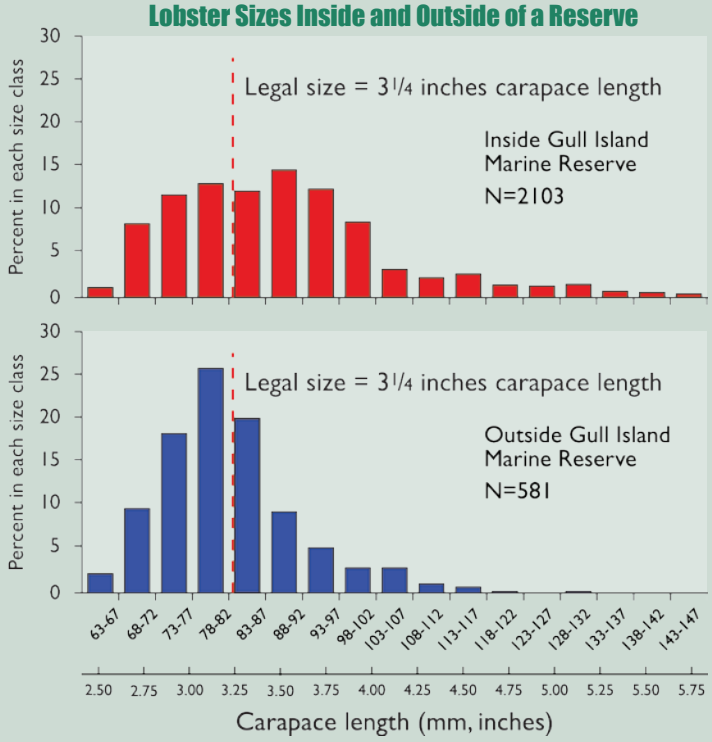
The short-term goals of CALobster are to determine:

1. sizes of spiny lobster and population age structure inside versus outside reserves,
2. number of lobster per trap inside versus outside reserves, and
3. movement patterns near reserve borders and over greater distances.

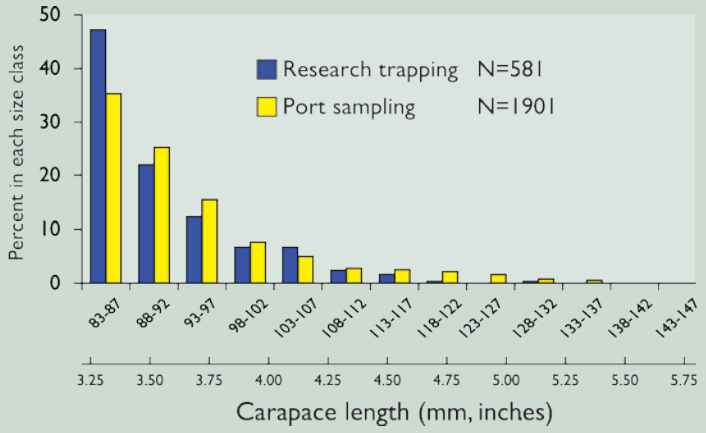
At the Gull Island Marine Reserve, for example, the monitoring program's traps inside the reserve (top graph) consistently caught more legal-sized lobster than traps outside (middle graph). Additionally, the largest lobster sampled during surveys were found inside the reserve. Monitoring at other reserves produced similar results, suggesting that the reserves affect lobster populations at the Channel Islands. Scientists expect this trend to become even more apparent as time passes and lobster in reserves continue to grow.

At mainland ports, CALobster works with commercial fishermen to collect data on their lobster catch. Port sampling helps CALobster relate monitoring data from the islands to fishery data from a larger region and longer time periods. It also enables lobstermen to contribute to the monitoring and management of fishery resources. The bottom graph shows that port sampling (yellow bars) and research sampling (blue bars) produced similar results.

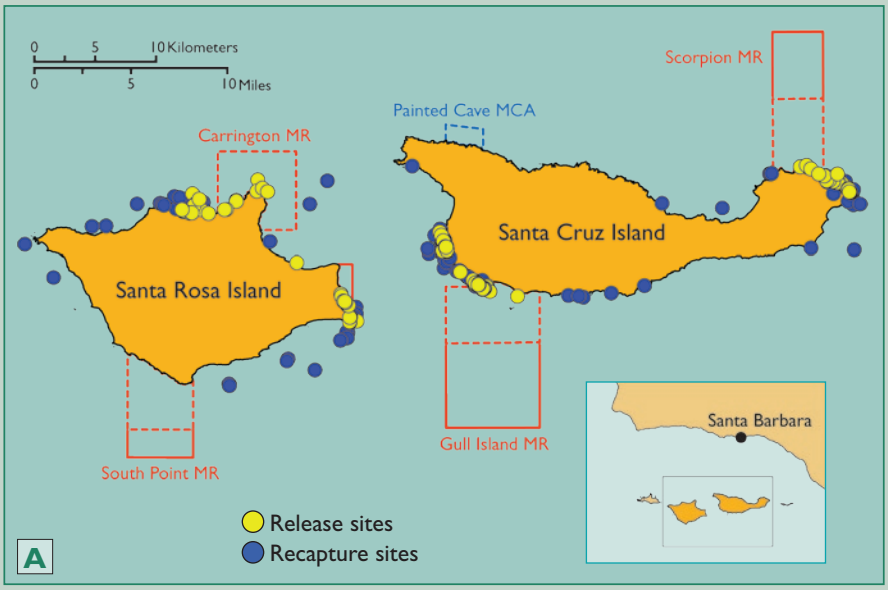
Lobster Sizes Inside and Outside of a Reserve

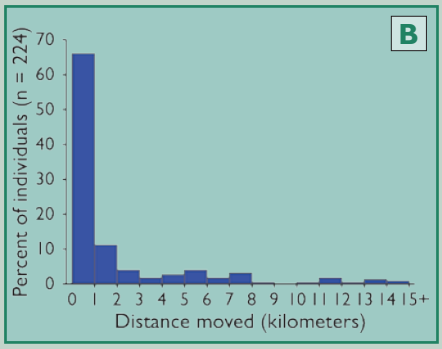


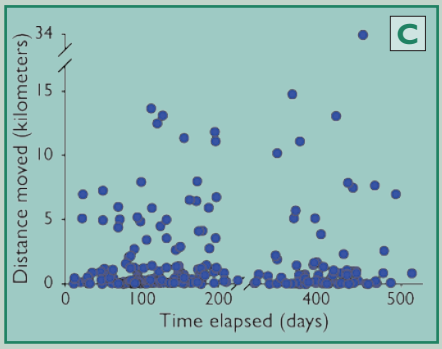
Research and Port Sampling of Lobster Outside Reserves



Numbers do not represent abundance







Lobster Movement

A. Over a period of 2 years, scientists tagged and released lobster inside and outside 4 marine reserves at the Channel Islands. Sites where tagged lobster were released are indicated by yellow dots. When commercial fishermen caught tagged lobster outside reserves, they reported the locations (blue dots) to the scientists.

MR is Marine Reserve.
MCA is Marine Conservation Area.

B. This graph shows the distances that lobster had moved after being tagged. More than 60% traveled 1 kilometer or less, but some moved 15 or more kilometers.

C. This graph shows the distance that individual lobster traveled from the time they were tagged to the time they were caught in a commercial fisherman's trap. Some lobster were recaptured near their release sites even after 2 years, whereas other lobster traveled several kilometers within a hundred days. The graph covers 2 lobster fishing seasons; the break in the x-axis indicates the closed season.

Collaboration of Fishermen and Scientists

CALobster strives to advance fishery research and management by fostering collaboration among scientists and fishermen. As part of these collaborative efforts, CALobster conducts studies in which lobster are tagged, released, and eventually recaptured. The studies provide information about where lobster go and how fast they grow. The data may be valuable for understanding how marine reserves affect the lobster fishery, developing lobster population models, and integrating marine reserves into stock assessments.

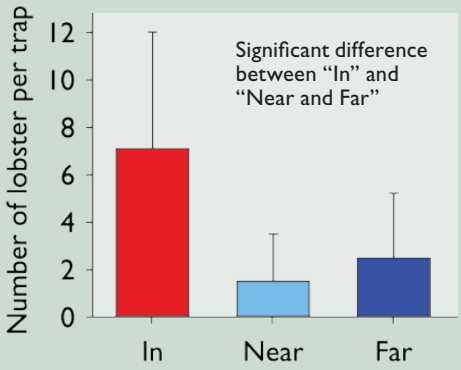
During a 2-year period, researchers tagged 14,000 lobster and studied movement across reserve borders. Commercial fishermen recaptured and reported the exact location of 224 of these tagged lobster. The map above shows the recapture locations, as well as initial release points. This study revealed that most lobster traveled only short distances, even after two years (see figures, above).

CALobster researchers put lobster traps inside reserves and at different distances from the reserves. Although the number of lobster captured per trap varied, the difference between reserves and fished areas was significant. On average, the number of lobster captured per trap inside reserves (red bar, right) was more than twice the number captured in fished areas near and distant from the reserves (light and dark blue bars, right). The researchers are investigating potential causes of these patterns, including reserve protection, historical distribution of lobster, and differences in habitats.

Data from CALobster. Analysis by M. Kay, H. Lenihan, C. Miller, and K. Barsky.

Key Findings

- Lobster populations inside reserves have higher proportions of large individuals.
- Traps inside reserves consistently had equal or higher yields than traps outside.
- Recaptures suggest most movement is less than 1 kilometer, but some lobster move long distances.



Average number of lobster per trap inside, near, and farther (up to 2 miles) from reserves.

How Much Time Do Fish Spend in Marine Protected Areas?

California sheephead. *Photo: Robert Schwemmer/ NOAA*

Cabezon. *Photo: Chad King/MBNMS*

Giant seabass. *Photo: © Douglas Klug*

Fish Move into and out of Reserves

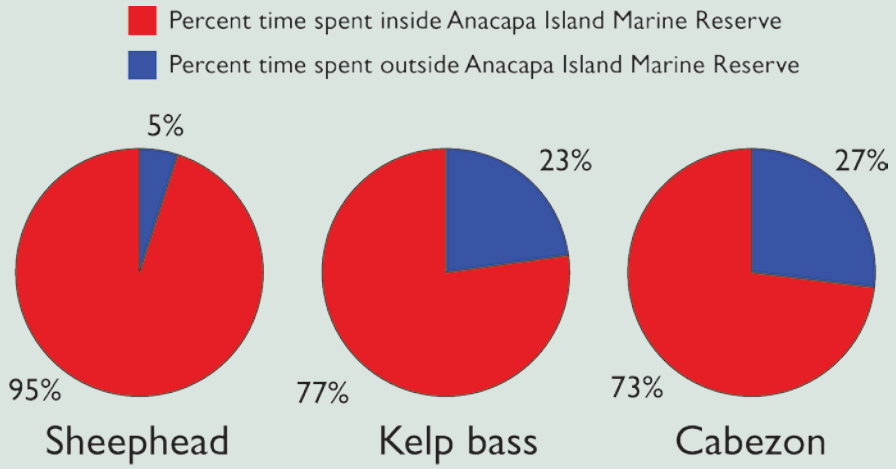
Some fish species roam over great distances, while others tend to stay in a relatively small area. Because fish at the Channel Islands are protected from fishing only while in marine reserves, their travel habits are a key factor in how well they are protected. In 2000, scientists began tracking fish movements around the islands. They tagged 224 fish with small transmitters and then monitored the fishes' movements using 98 listening stations on the seabed. The study included 4 fish species: California sheephead, kelp bass, cabezon, and giant sea bass. Some individuals of each species moved from reserves to surrounding waters, but the species varied greatly in how far they traveled. California sheephead tagged inside a marine reserve at Anacapa Island stayed in the no-fishing area 95% of the time. Many tagged kelp bass and cabezon stayed in the reserve, but some left and did not return. Giant sea bass tended to move farthest, traveling more than 50 miles among the islands and the mainland. Even so, they were in marine reserves about 25% of the occasions on which scientists knew their whereabouts. Because these fish species vary in time spent inside marine reserves, they receive differing amounts of protection from the reserves.

Data and analysis:J. Lindholm, A. Knight, D. Kline, M. Domeier, and J. Caselle.

Key Findings

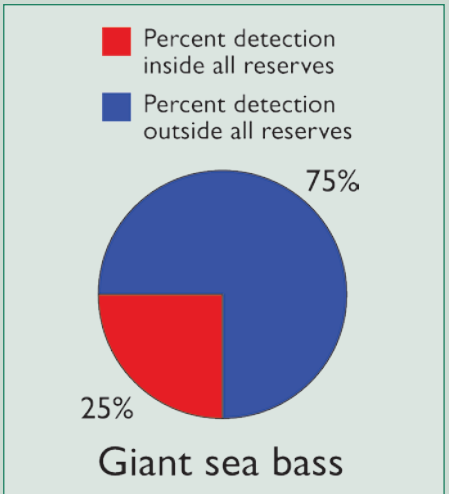
- After fish were tagged in a marine reserve, at least some individuals of each of 4 species moved out of the reserve.
- California sheephead stayed in the reserve 95% of the time.
- Cabezon and kelp bass stayed in the reserve 73% and 77% of the time, respectively.
- Although giant sea bass moved long distances, tagged fish were detected frequently in reserves.

Fish Movements at Anacapa Island



These 3 graphs show how much time fishes tagged in the Anacapa Island Marine Reserve spent in the reserve (red) versus outside (blue). California sheephead only left the reserve 5% of the time. Kelp bass and cabezon spent more time outside (23% and 27%, respectively).

All Islands



This graph shows that tagged giant sea bass were inside the marine reserves on 25% of the occasions when scientists could detect their whereabouts.

Changes in Marine Communities Inside Marine Reserves

Forest of giant kelp. *Photo: Laura Francis*

Purple urchins and a garibaldi. *Photo: Claire Fackler/NOAA*

Sunflower sea star. *Photo: Claire Fackler/NOAA*

Lobster, Scallops, and Some Fish Thrive in Reserves

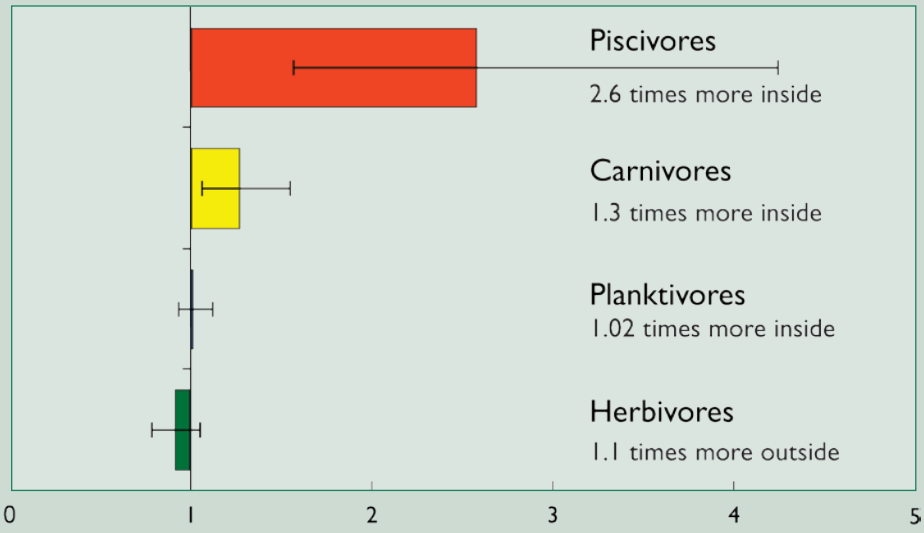
Marine reserves throughout California tend to host different fish, invertebrates, and seaweeds than areas that are open to fishing, but these differences can take years to develop. Lobster, turban snails, and sponges are abundant in the marine reserves, while purple urchins, sunflower stars, and Kellet's whelk are more common outside. These differences may have broad effects on the ecosystem. Monitoring conducted since 1982 by the Channel Islands National Park (CINP) shows that lobster, rock scallops, and sea cucumbers have become plentiful; different fish species dominate; and kelp forest and seaweed communities are less variable in a long-established marine reserve at Anacapa Island than in nearby fished areas. More recent monitoring by the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) is detecting similar ecological changes in reserves established in 2003. In addition to finding more fish species in reserves than in non-reserve areas, PISCO's surveys show that on average reserves harbor 2.6 times more biomass of predatory fish (red bar, below), which are targeted by fishermen outside reserves.

Data: PISCO and CINP. Analysis: S. Hamilton, J. Caselle, D. Malone, D. Kushner, and M. Carr.

Key Findings

- The number of fish species in marine reserves is greater than other areas.
- Reserves protect a more natural food web structure, including greater numbers of predatory fish and lobster, than fished areas.
- Kelp forest communities in reserves are less variable than those in places where fishing occurs.

Biomass of Fish Inside and Outside Marine Reserves



The graph above shows average ratios of fish biomass inside reserves versus outside reserves. Average ratios are given with one standard error.

Roles in the Food Web